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I. Foreword

The known deposits of useful ores, minerals, and types of rock on the Kola Peninsula are described in this survey. The intention has been to give a picture of the mineral resources of the peninsula. The deposits known to be under exploitation have been discussed in greater detail than the others. Production figures and estimates of reserves have been given whenever available.

Deposits known to be worked have not been discussed in one single chapter. They are to be found in the systematic description of the various mineral deposits. The development of mining of the Kola Peninsula has progressed - and is still progressing - so rapidly that it is impossible to keep a survey such as this up to date. Many more deposits must be regarded as under exploitation than are indicated. For the most part it is safe to assume that those deposits described as promising are being worked. The sources upon which this study is based are Russian scientific and technical works, dating from 1933 to 1941, and two German military-geographic surveys dated 1 June 1941 and 1 February 1943, respectively.

To a large extent this survey has been so arranged that the various raw materials and their deposits are described without regard to their geographical occurrence. When concerning clearly defined ore-areas, as, for example, the Khibine tundra, the deposits of the various raw materials are described under one heading in order that a clear picture of the importance of the area as an industrial center may be obtained.

20 October 1948

II. Introduction

Today the Kola Peninsula is one of the most important industrial areas in the Soviet Union. It is based first and foremost on the enormous apatite and nephelite deposits in the central parts of the peninsula - on the Khibine tundra.

The apatite provides the basis for an extensive phosphate industry as well as for chemical industries of various sorts. The nephelite is of primary importance to the aluminum industry, the glass industry, and the porcelain ~~procelain~~-ceramic industry.

In addition to the main products, apatite and nephelite, the Khibine area yields sodium, potassium, iron, titanium, vanadium, strontium, fluorine, and rare-earth products. The production of niobium, tantalum, uranium, and thorium is less extensive at the present time. However, this is to be expanded considerably, particularly the production of the steel-alloying metals, niobium and tantalum. There is also the possibility of producing a rather small quantity of molybdenum.

The Lovozero tundra is separated from the Khibine tundra by Lake Umbozero. The Khibine tundra and the Lovozero tundra may be considered an ore region. As yet there is no significant exploitation of the Lovozero tundra. However, extensive investigation has been conducted there, and extraction of many metals has been pursued experimentally. There is no doubt that the Lovozero tundra will foster a thriving mining industry in the near future, particularly for the extraction of zirconium ore (eudialyte), niobium, and the rare-earth metals.

The deposits of apatite, nephelite, and the rare-earth metals are the largest in the world. The deposits of zirconium, niobium, and tantalum are also enormous.

The ores on the Khibine and Lovozero tundras are very complex in composition. These are the only places in the world where deposits of this type can be exploited economically. But in order to do this, it has been necessary to introduce completely new methods of concentration. The further processing of the previously unknown minerals - especially of zirconium, niobium, and tantalum - has also necessitated the development of new technical processes .

Other ore deposits on the Kola Peninsula which must be especially emphasized are the important nickel mines around Monchegorsk, the iron mines at Lake Kovdor, and the titanium-iron ores at Afrikanda.

The Petsamo nickel mines - the largest in Europe - must also be mentioned ~~metnicned~~ in a discussion of the raw material resources of the Kola Peninsula. The Russians obtained these under the terms of the peace treaty made with Finland in 1947.

The production of quartz, mica, and feldspar is important. Fuel reserves in the form of peat are colossal. Building stone and roofing slate are found in inexhaustible quantities. There are also unlimited amounts of raw material for fire-resistant substances and abrasives, but the exploitation of these minerals has barely begun so far.

Many metal and mineral deposits have been investigated but have not yet been worked, partially because of the lack of transportation facilities.

The Kola Peninsula is far from being completely investigated. There are possibilities for further utilization of the mineral wealth. If one looks at a map, it will be noticed that the main deposits are grouped around the Kirov railroad line. In the eastern parts of the peninsula several mineralized areas have been recorded, the importance of which is not yet known sufficiently. With the continued development of the transportation system in these areas, it is certain that many of them will admit development to valuable mines.

It can be safely stated that the Kola Peninsula will assume greater and greater importance as a source of raw materials for the Soviet Union with the coming years.

III. A Short Geological Description of the Khibine Tundra and the Lovozero Tundra

The Khibine tundra is a high plateau between Lakes Imandra and Umbozero. Geologically it is composed of a complex of various types of alkali rock, many of which resemble individual types of rock in the Oslo area - and more particularly in the Fen area at Ulefoss. There are only a relatively few places in the world with such rock types and most of these fields are rather small. However, the Khibine field covers an area of 1,327 square kilometers.

Separated from the Khibine field only by Lake Umbozero is the Lovozero field, which is similar to the Khibine field, but not completely analogous to it. The Lovozero field is approximately half as large as the Khibine field - 650 square kilometers.

The various types of rock of the Khibine field lie in a horse-shoe shaped massif, the open side of which faces toward the east.

The same is the case with the Lovozero field.

The ore deposits in both areas are fund along mineralised zones, usually on the boundary or near the boundary between two types of rock. Generally they lie in semi-circular zones.

By far the most important ore is the apatite-nephelite ore, which is the basis for the industrial city of Kirovsk. The ore occurs in pockets containing apatite and nephelite in varying amounts.

The apatite-nephelite ore is found associated with iyolite (ijolit)-urtite types of rock. One speaks of an outer ring, a middle ring, and an inner ring of apatite-nephelite ore in the Khibine field. The deposits lying along the middle ring are the largest and it is only these which are being worked.

Apatite-nephelite ore is also found at one place in the Lovozero tundra, but this is a small and poor deposit compared to those on the Khibine tundra.

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IV. Apatite - Nephelite Ore

Apatite-nephelite ore occurs in great quantities on the Khibine tundra. These deposits are the world's largest apatite deposits, representing over a billion tons of apatite. Besides this, the deposits also contain about a billion tons of nephelite.

In addition to the deposits on the Khibine tundra, there are also smaller deposits on the Lovozero tundra and near Lake Kovdor - occurring in conjunction with the Koldgrovo iron ore deposits, 150 km northwest of Kandalaksha. The location of the various deposits is shown on Fig 3. In this study only the deposits on the Khibine tundra will be described, as none of the others can conceivably assume economic importance in the very near future.

The various deposits on the Khibine tundra contain, for the most part, the same types of apatite-nephelite ore. For that reason ore from the different deposits can be processed by the same concentration plants. The Kukisvumchorr and ~~Iapeparr~~ Yukspork deposits are the largest. Most of the output comes from these two deposits. To what extent the other deposits are being worked is not known. All the deposits indicated on the map, however, have been completely investigated and can be worked at any time. The location of the deposits on the Khibine tundra is shown on Fig 2.

A. The Composition of the Ore

The apatite-nephelite ores can be divided from their appearance into three types, a so-called "speckled" ore, a streaked ore, and a veined ore. The speckled ore always occurs in the upper part of the deposit and contains 70-80 percent apatite, 10-20 percent nephelite, 4-8 percent aegerite ($Na\ Fe\ Si_2\ O_6$), and 2 percent titanite ($Ca\ Ti\ SiO_5$) and titanium-magnetite. The streaked type of ore lies beneath the speckled type and has a lower apatite content, but a higher nephelite content; its composition is 40-50 percent apatite, 30-40 percent nephelite, 20 percent aegerite, titanite and titanium magnetite. The veined ore is the lowest layer and has a lower apatite content than the other two types mentioned and a correspondingly higher nephelite content. (For accurate analyses of the various types of apatite ore, see A.E. ~~Fersmanis~~ Fersmann's "Nützliche Bodenschätze der Kola

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Halbinsel", Moscow-Leningrad 1941, page 332).

As a rule, when mining it is impossible to separate the different types of ore. At the largest mine, Yuksporr, the crude ore contains about 25 percent P_2O_5. The fluorine content is unusually high, and in pure apatite can run as high as 3 percent. Generally the ore has a strontium content of 2-3 percent and a rare-earth content of somewhat less than 1 percent.

B. Concentration and Further Utilization of the Products

The crude ore is shipped to Kirovsk and milled and concentrated in the apatite works there. The ore must be milled to a granular size of 0.074 mm. It is milled to this size for subsequent processing to superphosphate, although a granule size of 0.15 mm would be more suitable for flotation alone. Such fine-milling results in fairly large losses in the form of dust. When the apatite works is in operation, it is constantly enveloped in a cloud of dust.

The milled crude ore is subjected to flotation in a reagent consisting of a mixture of olein and peat acid (torvsyre). The peat acid is manufactured at a plant at Laplandiya Station on the Kirov railroad line.

1. The Apatite Concentrate.

By means of the flotation process, an apatite concentration containing 40 percent P_2O_5, 52 percent CaO, 3 percent F, and 1 percent rare earth metals is obtained. This concentrate is richer than the best North African or Florida phosphates. Because of its unusually high content of phosphorus, lime, and fluorine, the Kola apatite is more suitable for blast furnace flux than any other apatite. The apatite concentrate comprises 60 percent of the quantity of crude ore. The waste, consisting chiefly of nephelite, therefore constitutes 40 percent of the quantity of crude ore. This waste consists of 70 percent nephelite, 6 percent apatite, 5-7 percent aegerite, 6 percent hornblende, 5 percent mica, 3 percent titanite ($CaTiSiO_5$) and 2-3 percent titanium magnetite.

The waste is processed further in the nephelite works in Kirovsk. There a magnetic separation process is utilized, yielding a concentrate of nephelite, a concentrate of aegerite and titanium magnetite, and unusable waste.

B. The nephelite concentrate contains:

30% Al_2O_3

42% SiO_2

2-2.5% FeO

2-2.5% CaO

5-6% K_2O

12-13% Na_2O

0.5-0.7% P_2O_5

The nephelite concentrate is utilized in the production of aluminum, alkalis, Portland ~~Rent and~~ cement, and raw materials for the glass and ceramic industry and the leather industry are derived therefrom. 8-10 tons of lime and 4.5 tons of coal are required to produce 1 ton of Al_2O_3. Lime of the desired quality is not found on the Kola Peninsula and there is no coal at all. An aluminum plant has been built in Sasnoyets near Kandalaksha. The idea was to utilize the lime from Lake Kovdar (Yena District), near the Kolderovo iron mines. However, this lime turned out to have too high a silicic acid content (8% SiO_2). For that reason the major portion of the nephelite used for the production of aluminum is sent to the aluminum plant at Volkhovstroy, east of Leningrad, where there is ready access to high-grade lime. A portion of the aluminum oxide produced at Volkhovstroy is shipped to the plant at Kandalaksha, which must limit itself to the production of metallic aluminum from the oxide. In the valley of the Laparskaya River, east of Lake Vudyavr, near Kirovsk, there is an experimental plant for the processing of nephelite.

3. The Aegerite-Titanium Magnetite Concentrate

By subjecting the "Waste" from the flotation of the apatite to a magnetic separation process the nephelite plant in Kirovsk obtains in addition to the nephelite concentrate already mentioned. An aegerite-titanium magnetite concentrate. This comprised 10% of the crude ore. The aegerite component of the concentrate contains 0.2-0.9% vanadium oxide (V_2O_5) and the titanium magnetite component contains 1.0-1.5% vanadium oxide.

Declassified and Approved For Release 2012/04/06 : CIA-RDP82-00039R000100020050-4

The concentrate is used in the production of titanium white, titaniferous iron, and vanadiferous iron. The processing of 200,000 tons of nephelite concentrate (See the section "Production" further on) will yield 5,000-6,000 tons of titanium magnetite concentrate containing about 16% TiO_2 and 0.5-1.5% V_2O_5.

In 1941 plans were being prepared for a titanium magnetite foundry at ~~Sasheyek~~ zasheyek (a station on the Kirov railroad line) on the south side of Lake Imandra. It is not known to what extent these plans have been realized. In this instance the intention was to utilize aegerite as a flux in order to reduce the melting paint of the ore (because of the high alkaline content of the aegerite). At the same time the aegerite would offer the advantage of providing the ore with more Vanadium. Vanadium would, of course, go into the slag, but it could readily be extracted therefrom.

4. Pyrophosphate From Apatite.

Pyrophosphate is a phosphate obtained from the calcining and further processing of apatite. Certain types of earth can extract (utilize) the phosphorus content of the Thermophosphate.

Sulphuric acid, which is expensive and difficultly accessible on the Kola Peninsula, is not used in the production of thermophosphate but it is necessary in the production of superphosphate.

Plans for the production of thermophosphate from milled Apatite ore by reaction with alkali were completed about 1941. This project was carried out at the phosphorus plant east of Lake Vudyavr. However, technical difficulties, were soon encountered, as the apatite-alkaline mass had a tendency to adhere to the walls of the furnace when brought to a red heat. A large part of the raw materials thus took no part in the reaction and the yield was poor. During the war "Molotov Cocktails" were produced by the phosphorus plant, and further work on the project was dropped. Undoubtedly the project was taken up again after the war and the problems, in all likelihood, have been solved.

5. Lime From Apatite.

As previously mentioned high-grade lime deposits do not occur on the Kola Peninsula. For that reason, production of lime from apatite concentrates containing 50% calcium oxide has been attempted. For the most part, the planned process is as follows: burning of the Apatite concentrate in order to rid it of organic substances introduced during flotation with olein and peat acid. Then the roasted concentrate is treated with ~~metric~~ nitric acid, producing calcium nitrate (which contains 80% of the calcium in the apatite concentrate - therefore a satisfactory yield). Electrolysis of this product yields lime and nitric acid. To what extent this process is used in actual practice is not known. If it is economically feasible to make use of this process, it will be passible to satisfy the lime requirements for the production of aluminum of the Kola Peninsula.

6. The Rare-earth Metals, Particularly Lanthanum, Yttrium, and Cerium.

The apatite-nephelite ore contains slightly less than 1% rare-earth metals. During the flotation process these settle in the apatite concentrate, from which they can be extracted in appreciable quantities by further processing. The largest deposits of these valuable metals are generally at the Lovozero Tundra laparite deposits.

7. Fluorine.

The apatite concentrate contains about 3% fluorine. About 15,00 tons of pure fluorine or 40,000-50,000 tons of calcium fluoride can be produced from a million tons of apatite concentrate.

8. Phosphoric Acid

A treatise by A. E. Fersmann, dated 1937, mentions that the production of large quantities of phosphoric acid from apatite was planned; this acid was to be utilized by the various chemical industries" which are now under construction on the Kola Peninsula." The Kola Peninsula lacks suitable raw materials (pyrites) for the production of sulphuric acid, and the intention in this case was, by developing new processes for the chemical industry, to be able to replace sulphuric acid with phosphoric acid. It has not been possible to find out whether or not this is being done on a large scale.

C. Production

Most of the ore production comes from Kukisvumchorr and Yukspørr. The ore is mine partially from surface-outcroppings and partially from minis. In 1939 one million tons were dug from surface outcroppings and two million tons from minis.

The total production of apatite-nephelite ore in 1938 was 2,200,000 tons; in 1939 it was three million tons. The major portion of the apatite concentrate was delivered to various superphosphate plants all over the European part of the Soviet Union. In 1939 there was no sulphuric acid on the Kola Peninsula for the production of superphosphates. It is possible that sulphuric acid is available there now, making it possible to produce superphosphate to some extent on the spot.

However, it is certain that the overwhelming part of the apatite concentrate is still exported.

In 1938, 620,000 tons were delivered abroad. For the most part, this was apatite concentrate, but there was also some crude ore, apatite-nephelite ore. German, Belgium, Luxembourg, and England were the chief importer countries. In 1939 the nephelite works at Kirovsk produced 200,000 tons of nephelite concentrate. A production of three million tons of crude ore (1939), however, should yield 775,000 tons of nephelite concentrate. The reason that the ore production was not completely utilized is, apparently, that the nephelite works had too low a capacity. It looks as if part of nephelite concentrate together with the rock waste, is being dumped into the Belaya River, for already there are discussions in Russian trade literature as to the best method of salvaging the nephelite which has collected in the Belaya.

D. Ore Reserves

In 1934 the reserve of apatite-nephelite crude ore in the middle apatite ring on the Khibine tundra was estimated to be 1,960 million tons. This takes into account only the ore ~~hx~~ lying above the surface of the lake.

To this must be added the apatite in the inner and outer rings and in the saamite. None of the deposits have been worked. The total reserve of crude ore may be estimated at over two billion tons. This corresponds to over a billion tons of apatite.

The reserves of the individual deposits are (1934):

Kukisvumchorr-Yuksporr	1,290	Million	tons
Rasvumchorr I	160	"	"
Rasvumchorr II	440	"	"
Soluaiv-Nyurkpakhk	25	"	"
Kuel'por	40	"	"

E. Transportation Conditions

The ore from the Kukisvumchorr-Yuksporr deposits is shipped to the city of Nefelin. Until 1934 this was done by horse and wagon. In 1935 plans were laid for motorizing transportation and, apparently, this was done long ago. The ore is transported by railroad from Nefelin to the concentration works in Kirovsk. The apatite and nephelite concentrates produced there are shipped by railroad to Murmansk and Kandalaksha. From Kandalaksha they are shipped through the Stalin Canal to Leningrad and further distributed from there. Apparently a portion of it goes over the Vologda Line via Arkhangelsk to Moscow. Ore exported to England, Germany, Belgium, and Luxembourg goes mainly by way of Murmansk, but some of it is also exported from Leningrad.

F. More detailed description of the Kukisvumchorr-Yuksporr deposits

The Kukisvumchorr and Yuksporr deposits have a common origin. They are separated only by the valley of Loparskaya River. Apparently the two deposits are connected beneath the soil of the valley. Only the Kukisvumchorr ore deposit is 2.8 km long and 40-75 meters thick; it runs in a NNW-SSE direction. The deposit is situated in iyolite-urtite rock, traversed by veins of titanuim magnetite, aegerite, zeolite, etc.

The ore occurs in two types:

Apaneite with 20-35% P_2O_5 and 15-7% [Sic] Al_2O_3

Neopite with 7-8% and 21% Al_2O_3

For accurate analyses of the various apatite-nephelite ores, see: Fersmann, "Useful Minerals of the Kola Peninsula" (Nützliche Bodenschätze der Kola Halbinsel), Moscow-Leningrad, 1941, p.322.

The ore is extracted partially from shafts in the mountain sides.

(TN: drift = horizontal Shaft)

Mostly apaneite is obtained from the outcroppings - and this is the best phosphate ore. A large part of this does not go to the apatite works in Kirovsk, but is sent to the city of Nefelin, where it is ground, and before the war was exported via Murmansk to England and Germany.

Mining operations is the five different levels where drifts have been excavated. There is a 30 m gap between each drift and they are at an altitude between 380 and 580 meters. (The report states in parentheses - "What the quoted altitude figures are referred to is not known; possibly they are figuring them from the bottom of the valley.") Operation at seven new levels was planned in 1942. The total length of the drifts the various levels was 400 km in 1942. In 1941 the longest drift was 3 km long.

There is a dumping shaft between the various levels, and the ore mined at the various levels is dumped down to a loading chamber at the lowest level. In the loading chamber the ore is loaded into 5-ton cars on tracks and transported through a tunnel or drift to the outside.

The labor force at the mines at Kukisvumcharr and Yukspеrr amounted to about 300 workers in 1942.

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N. I. Godovikov: "On the Question of the Geological Exploration of the Apatite-Nephelite Deposits at Kukisvumchorr and the Nature of its Ores" (Russian)

P. N. Vladimirov: "The New Project of Mining Operations at the Apatite-Nephelite Deposits at Kukisvumchorr, Collection of Reports No VI, "Khibine Apatite", Leningrad, 1933 (Russian)

V. Nephelite

The nephelite has the chemical formula (Na+K) Al SiO_4. Analysis yields 45% SiO_2, 35% Al_2O_3, and 20% Na_2O (+ K_2O).

Nephelite is mined economically at present on the Kola Peninsula only in conjunction with the mining of the apatite-nephelite ore of the Khibine tundra, i.e., The Kukisvumchorr-Yukspórr deposits in particular.

Besides from the apatite-nephelite ore, nephelite may be extracted profitably from three other types of deposits. All of these deposits occur on the Khibine tundra. The deposits are:

A. Nephelite as a by product of apatite concentration at Kirovsk.

B. Nephelite concentration in urtite rock

a. Kukisvumchorr

b. Yukspórr

c. Apatitovyy-Otrog

d. Rasvumchorr

C. Nephelite Sand-clays

e. Paschannyy Navolok

f. Gol'tsovka

D. Nephelite mud as a waste-product of apatite concentration in Kirovsk

g. The mouth of the Belaya River at Lake Imandra

h. The Belaya Bay.

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A. Nephelite as a by product of apatite concentration at Kirovsk.

B. Nephelite concentration in urtite rock

  a. Kukisvumchorr

  b. Yukspor

  c. Apatitovyy-Otrog

  d. Rasvumchorr

C. Nephelite Sand-clays

  e. Peschannyy Navolok

  f. Gol'tsovka

D. Nephelite mud as a waste-product of apatite concentration in Kirovsk

  g. The mouth of the Belaya River at Lake Imandra

  h. The Belaya Bay.

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A. Nephelite as a by-product of apatite concentration in Kirovsk.

This is the most important source of nephelite at the present time. The reserves there are of the magnitude of one billion tons of nephelite. In 1939 the annual production was 200,000 tons of nephelite concentrate

B. Nephelite in Urtite.

The reserves of nephelite in urtite and iyolite comprise, in all, several billion tons. However, the greatest part of the deposits contain aegerite also, which is associated with the nephelite in such a manner that the two minerals cannot be separated magnetically. This decreases the value of the ore greatly, and at present such deposits are not utilized as a source of nephelite. Only a relatively small part of the deposit has ore containing 90% nephelite. This nephelite ore is high-grade and can be utilized without further processing. The following deposits consist partially of such high-grade are:

Kukisvumchorr (Same geographical area as the apatite-nephelite ore); reserves: 700,000 tons

Yukspørr (Same geographical area as the apatite-nephelite ore); reserves: 1,300,000 tons

Apatitovyy Oxrog; reserves: 2,900,000 tons

Rasvumchorr (Same geographical Area as the apatite-nephelite ore); reserves: 2,100,000 tons

Total reserves: 7,000,000 tons.

Quite recently light urtite with high nephelite content has been discovered in the southern part of the Khibine tundra - likewise, nephelite deposits containing 95% nephelite and a small quantity of iron in the southern part of the Lovozero tundra.

In addition to this there are billions of tons of khibinite rock, which occurs widely on the Khibine tundra. The nephelite in the Khibinite, however, cannot be extracted economically. On the other hand, khibinite is widely used as a construction material because of its excellent insulating properties.

C. Nephelite Sand-Clays

Nephelite sand consists of completely eroded nephelite rock which has been transported by the water of the rivers on the eastern side of Lake Imandra and deposited. This sand contains about 75% nephelite and 4-5% iron. This iron content can be reduced to about 0.7 percent by magnetic concentration. Nephelite sand is particularly suited for the production of special cement. It is not so well suited for the glass industry. The mining of nephelite sand is very cheap. In 1941 the cost of mining was 2-3 rubles per ton. It is not known how great production is. According to unconfirmed information, it is shipped to the Sosnovets plant north of Kandalaksha. The reserves of nephelite sand at the Peschannyy Navalok and Gol'tsovka deposits are estimated at five million tons. Taking other deposits into account, the total reserves are estimated to be about ten million tons.

D. Nephelite Mud as a by-product of apatite concentration at Kirovsk.

By 1939 five million tons of finely ground nephelite rock was thrown into the Belaya River. This was nephelite rock which the nephelite plant at Kirovsk could not process; This ground nephelite rock has been transported by the Belaya River to its mouth at Belaya Bay at Lake Imandra. In transportation the rock has undergone a sorting by specific weight; the heavier constituents, like titanium magnetite and aegerite have sunk to the bottom after being transported only a short distance, settling along the upper course of the river. The lighter nephelite has settled only at the mouth of the river and in Belaya Bay itself. These deposits contain about 75 percent nephelite. The nephelite can be dredged up without difficulty. This nephelite is suitable for the production of cheap glass and glass insulators. It can also be used in the ceramic industry. It is estimated that 1,500,000 tons of sand containing 75 percent nephelite has been deposited at the mouth of the Belaya River and about two million tons in Belaya Bay.

E. Transportation Conditions

All of the nephelite deposits lie in the vicinity of the Kirov railroad line or the branch line to Kirovsk.

Literature:

A. E. Fersmann: "Useful Minerals of the Kola Peninsula; Moscow-Leningrad, 1941 (Russian).

VI. Saamite

Saamite is an independent type of apatite ore differing from the ordinary apatite ore on the Kola Peninsula. Ordinary apatite has the formula $Ca_5(PO_4)_3\ Cl$, therefore a calcium chloride-phosphate. In saamite, however, much of the calcium has been replaced by strontium and the rare-earth metals. It contains up to 12 percent strontium and up to 5 percent rare-earth metals. It is of particular importance as a source of strontium.

A. Deposits and Mining

The most important deposit is that of Peachvumchorr, which is situated to the southwest of Kukisvumchorr (the largest apatite-nephelite deposit), is separated from this by the Kukisvum valley. 100 meters thick, the reserves are estimated at 3-4 million tons. Possibly the reserves are ten times greater, as it is possible that the deposit continues beneath the valley floor up toward Kukisvumchorr. There is still another deposit, Aoveslogchorr, near Kirovsk - but its exact location was not indicated on the map.

Exploitation of the saamite deposits was still in the preliminary stages in 1942. However, important research projects and planning for future operation had already been made. It is not known if operation is now in progress, but it is very possible.

In 1942 it was planned to mine 100,000 tons of ore per year, from which it was expected to extract 5,000 tons of strontium sulphate, about 1,500 tons of rare-earth metals, and 40,000 tons of phosphate. The chemical-technical methods of processing the ore were discussed in detail in 1942. A group of engineers thought that it would be economically feasible to extract the strontium as a carbonate, a product which is considerably more valuable than strontium sulphate.

Transportation conditions are favorable as the deposit is located not far from Kirovsk.

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VII. Lovchorrite

So far, lovchorrite has been found only on the Khibine tundra. Prospectors have searched for it on the Lovozero tundra, too, but as yet without success. The richest deposits lie around Yukspor, especially in the Hackmann Valley, 67° 41'E - 39° 49'N. If one looks at the map he will see that the deposits occur in two conform zones. The inner zone has the richest deposits.

Lovchorrite is a fluorine-containing titanium silicate of very complex composition. The principal metals contained in it besides titanium are calcium, sodium, and strontium. In lesser quantities it contains rare-earth metals, mostly cerium-lanthanum metals and smaller amounts of yttrium, niobium, tantalum, and thorium.

A. Deposits and Operation

The ore is mined for its reare-earth, titanium, niobium, tantalum, and thorium content. The extraction of rare-earth metals was essential to profitable operation. Deposits in the Hackmann Valley were worked until 1941, when operations there ceased because of excessive production costs. Rare-earth metals were extracted in sufficient quantity and considerably cheaper from the concentration of apatite-nephelite ore in Kirovsk and the concentration of loparite. It is not likely that lovchorrite ore will regain its importance as a source of rare-earth metals in the very near future. New methods of processing could change the picture in a short time. For that reason we shall describe the ore and discuss its production.

Lovchorrite ore consists of large crystals of feldspar (30-40% of the ore, as a rule), large crystals of aegerite and titanium magnetite (30-40% of the ore, as a rule), small crystals of apatite (2-4% of the ore), with lovchorrite making up the percentage difference. As a rule, the lovchorrite component of the ore comprises 7-20%. In individual, rich pockets, the lovchorrite content may be as high as 50% - at the expense of the feldspar and aegerite - titanium magnetite components.

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The ore is mined partially from outcroppings and partially from horizontal shafts-drifts. The mine area in the Hackmann Valley, which used to be worked, covered an area of 1,800 meters x 250 meters. The ore occurs in veins about one meter thick, cutting through nephelite-syenite rock. There were at least 20 such veins in the mine area. The ore was crushed on the spot into lumps the size of a fist. The lumps with the highest lovchorrite content were sorted out by hand. These were transported by truck to a concentration plant, located on the eastern shore of Lake Vudyavr, similar to that at Kirovsk. A special road was built to accommodate this traffic from the mines to the concentration plant. The lovchorrite concentrate produced at the concentration plant was dried, packed in boxes, and shipped over the Kirov railroad line to Leningrad.

One source reports that the production in 1940 was 15-25 tons of crude ore per week, or an annual production of about 1,000 tons of crude ore. Another source reports that the production amounted to 15 tons of crude ore per day, or about 4,500 tons of crude ore per year. The latter figure is the more likely.

Only about 60% of the lovchorrite is extracted in the concentration process - the rest is thrown out with the waste. Concentration is done in the following manner: the ore is milled to about 1 mm in granular size and process on a vanning table. This separates the aegerite-lovchorrite from the feldspar waste. This aegerite-lovchorrite concentrate is then dried and subjected to a magnetic separation process. The lovchorrite remains unaffected by the magnetic separation process.

Literature:

A. E. Fersmann: "Useful Minerals of the Kola Peninsula," Moscow-Leningrad, 1941 (Russian)

A. E. Fersmann: "Minerals of the Khibine and Lovozero tundras," Moscow, 1937 (English)

D. N. Mikhalev: "The Yukspor Deposit of Lovchorrite" (article in "Collected Works" edited by Kupletsky) Papers of the Academy of Science of the USSR, Moscow-Leningrad, 1937 (Russian)

VIII. Loparite

Loparite is a mineral consisting of 9-12% niobium-tantalum oxide (8-11% Nb_2O_5, 1% Ta_2O_5), 40% titanium oxide, 33% rare-earth metals, 0.7-0.8% thorium oxide, 0.03-0.05% uranium, and $1.0\text{-}1.8 \times 10^{-9}$ radium.

Loparite occurs in not less than seven different types of ore containing 2-12% loparite. There has been nothing said so far about working the poorer ores.

A. Deposits

Loparite occurs particularly on the Lovozero tundra. There it is found throughout the entire massif, but especially in its outlying parts. For the most part, loparite occurs in conjunction with the nephelite-syenite rock, luyavrite. This rock contains small loparite crystals of magnitude 1-2 mm. In individual layers of the rock, there is a concentration of loparite and it is these layers which constitute the ore. The thickness of the layers varies between one and four meters. The seven types of ore are the following:

1. Loparite-luyavrite, which extends longitudinally for over 100 km. The ore lies in parallel layers. The upper layer, at an altitude of 300-700 meters above sea-level, is the richest. On the average, all layers of ore contain 2-3% of loparite.

2. Loparite-urtite I occurs throughout the massif. Deposits capable of being worked are found 400-700 meters above sea-level. The richest parts contain 7-12% loparite.

3. Loparite-malinite is found in the western parts of the massif at an altitude of 640-750 meters above sea-level. This layer is only 60-70 cm wide (thick ?) and 16 km long. It has a loparite content of 8-10%.

4. Loparite-bearing porphyritic luyavrite is found in the western parts of the massif, 100 meters above the loparite-urtite deposits. The loparite content is 5-6%.

5. Loparite-yuvite occurs in layers above the loparite-malinite deposits and is associated therewith by transition types of ore. It is a poor loparite ore and is not worth mining.

6. Loparite-urtite II is found in the southern parts of the Lovozero massif. The ore layers there are 1.5-2.5 meters thick and contain 5-8% loparite. Characteristic of this particular type of ore is the fact that it contains apatite with a strontium content up to 20%.

B. Reserves and Production

The loparite reserves of the Lovozero tundra have not been computed. They are, however, very significant. The deposits investigated to date alone represent over ten million tons. In 1939 a pilot plant was set up for experimental operation. It was planned to extract 500 tons of niobium and 1,500-2,000 tons of rare-earth metals per year. This would represent more than the present world requirement of rare-earth metals.

The pilot plant was built in Alluaiv in the northwestern corner of the Lovozero tundra. The names and the locations of the deposits being worked are not known. It is, however, quite conceivable that the Kuamdestpakhk in the eastern part of the massif is being worked as well as the deposits in the western and southern parts.

Loparite is not particularly widespread on the Khibine tundra. It occurs here and there in the central part of massif in conjunction with khibinite, but not in quantities sufficiently large to warrant mining. The only deposit of importance on the Khibine tundra is Mannepakhk on Lake Imandra. (Note: There is also a place with the same name on the Lovozero tundra!) There the loparite occurs in veins traversing the khibinite. The deposit is not worked.

C. Transportation Conditions

Transportation conditions are poor. There is a road from Pulozero (a station on the Kirov railroad line midway between Apatity and Murmansk) to the north end of Lake Lovozero, thus running north of the Lovozero massif. In 1941 two railroad projects were being worked on, one to lay a branch line from Kirovsk north of Lake Lovozero to the Lovozero massif, or a railroad line south of Lake Lovozero. It is not known if any of these projects have been realized or not.

Literature:

A.E. Fersmann: "Useful Minerals of the Kola Peninsula," Moscow-Leningrad, 1941 (Russian)

IX. Eudialyte (zirconium ore)

Eudialyte is a zirconium silicate containing 12-13% zirconium oxide. The mineral is present as a constituent part in several nephelite-syenite rocks both on the Lovozero tundra and the Khibine tundra. Eudialyte occurs on the Lovozero tundra mostly in conjunction with luyavrite rock. The ordinary type of luyavrite - of which the major portion of the Lovozero tundra consists - contains 20-25% eudialyte, i.e., there is a 3-4% zirconium oxide content in the rock. In the northwestern part of the Lovozero massive the eudialyte content of the luyavrite is somewhat lower - 13-20%. The best eudialyte ore there lies at an altitude of 900-1,000 meters above sea-level and occurs in luyavrite formations up to 200 meters thick.

Occasionally rather small pockets of highly concentrated eudialyte ore - containing up to 85% eudialyte - occur in the luyavrite. Besides this, veins of pegmatite up to 4 meters thick containing 25-55% eudialyte are sometimes found running through luyavrite and other rocks.

For the most part, eudialyte found on the Khibine tundra is associated with veins of pegmatite. There are, however, no veins of appreciable size and there are no rich enough veins to be considered for working.

A. Deposits and Reserves on the Lovozero Tundra

In the northwestern part of the Lovozero tundra alone the reserves of eudialyte reach forty-five million tons, with a eudialyte content of 13-20%. The most important deposit is Angwundaschorr mountain, where the reserves are estimated at fifteen million tons. The Strashempakhk deposit has not yet been sufficiently investigated, but it is possible that it is even larger.

Only in recent years have deposits of richer eudialyte ore been discovered, deposits containing 40-50% eudialyte and, in individual cases, up to 85%. These deposits however are considerably less extensive than those previously mentioned. They usually occur in pockets or layers five meters thick and 40-50 meters long. Numerous such pockets have been investigated in the Mannepakhk, Strashempakhk, Parganyun, Chivruaiv, and Engporr mountains.

Eudialyte occurs relatively rarely in the northern part of the Lovozero massif. However, it is there that the richest eudialyte deposit on the whole tundra is found, but it is slight in extent. This is the Vavnbed deposit, which is situated in the northeastern corner of the Lovozero tundra - near Lake Lovozero. There a layer several meters thick and containing 85% eudialyte has been discovered.

In the southwestern part of the Lovozero massif eighteen pegmatite veins containing 25-55% eudialyte have been discovered. The veins are about four meters thick and about 300 meters long. These deposits are accessible only with great difficulty.

B. Concentration

Since about 1935 there had been an attempt to work the eudialyte deposits, but production did not become a reality until about 1941. Until 1939 they had been working with the poorer eudialyte ores (about 20% eudialyte), but with the discovery of richer deposits, research was concentrated on them. It has not been possible to concentrate the poorer ores to a satisfactory degree. The concentration problem was solved in a purely technical way, but the yield was too poor for practical operation. Today only the higher-grade ores are used - containing 40% eudialyte or more, which corresponds to about 6% ZrO_2). However, the accessible deposits of this ore are too small to satisfy production as it was originally planned. Unless larger deposits of the high-grade ore have been discovered since the war, it is obvious that research on processing the poorer ores will continue.

It is not known where the eudialyte concentrating works are located. It is possible that it is at Alluaiv - the same place where the loparite concentrating works are. Eudialyte is obtained as a by-product in the concentration of loparite ore. The most important by-product in the concentration of eudialyte is aegerite.

No figures are known for the production of eudialyte.

C. Transportation Conditions

See under loparite.

Literature:

A.E. Fersmann: "Useful Minerals of the Kola Peninsula," Moscow-Leningrad, 1941 (Russian)

A.E. Fersmann: "Minerals of the Khibine and Lovozero tundras," Moscow, 1937 (English)

Pokrovskiy and Salie: "The Eudialyte Deposits of the Khibine and Lovozero Tundras," collected papers "The Rare Elements and Pyrrhotine of Khibine," Leningrad, 1933 (Russian)

X. Aegerite

Aegerite is a sodium ferro-silicate, $NaFeSi_2O_6$. It is obtained as a by-product in the mining of apatite-nephelite ore on the Khibine tundra and also in the mining of loparite ore, lovchorrite ore, and eudialyte ore.

The aegerite concentrate from the enrichment of apatite-nephelite ore is of particular importance as a vanadium raw material. In 1939 250 tons of vanadium oxide were extracted from aegerite-titanium magnetite concentrate. Undoubtedly, production is considerably larger now.

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Plans have been made for smelting the aegerite-titanium magnetite concentrate with nephelite in special blast furnaces, whereby cast iron with a phosphorus content is obtained. It was planned that this [steel] mill should be located at Zashcyek on the Kirov railroad line, at the southern end of Lake Imandra. To what extent the plan has been realized is not known.

It has also been planned to use aegerite as a flux in the smelting of other iron ores on the Kola Peninsula. These iron ores are characterized by a high melting point, which can be lowered by the alkaline quality of the aegerite.

XI. Sodalite (raw pigment)

Sodalite is a sodium-aluminum silicate containing chlorine. It occurs widely on the Lovozero tundra in association with veins of sodalite-nephelite-syenite. Sodalite is readily separable from the other components of the vein by washing. If the sodalite is heated to 700°C, a green pigment is obtained; if it is heated to 900°C, a blue pigment of ~~great~~ permanency - synthetic ultramarine - is obtained. Figures on the reserves or production of sodalite are not known.

The deposit on the Lovozero tundra which is being worked offers poor transportation facilities. The ore can be shipped out only during the winter and then by reindeer sleigh.

XII. Fluorspar and other Fluorine-containing Minerals

Minable, independent fluorite deposits have not yet been found on either the Khibine or Lovozero tundras - nor anywhere else on the Kola Peninsula. However, fluorite occurs widely and many rather small deposits are known. The possibilities of finding minable deposits are by no means exhausted. Nevertheless, fluorine is extracted as a by-product on the Khibine tundra, as indicated below.

Fluorite is being prospected for on the Khibine tundra around Kukisvumchorr, on the northern side of Poachvumchorr mountain and at Kuel'porr. Recently a small pocket of violet fluorspar was discovered near the top of Poachvumchorr.

Besides on the Khibine tundra, it is believed that there is a possibility of finding fluorspar deposits worth mining at the following places on the Kola Peninsula:

1. The nephelite-syenite area of Soustov, south of the station Titan on the branch line to Kirovsk. Numerous small veins of dark-green fluorspar, with crystals from 0.5-5.0 mm in size, have been found there.

Keyv

2. Alkali granites in the Keyev massif (Keiv) and other places in the eastern part of the Kola Peninsu'a contain much fluorspar. It is figured that there are good possibilites of finding minable deposits. It is also hoped that cryolite will be found there. Cryolite is another fluorine-containing mineral of great importance to the aluminum industry and which so far is known only from Ivigtut on Greenland.

3. Possibly there are fluorite deposits on Gremyakha tundra.

4. Small veins of fluorspar and amethyst have been found in the sandstone of Korabel Mountain.

5. Ten fluorspar-calcite veins 15-40 cm thick and containing 45-75% flurospar are known in the nephelite-syenite area on Cape Turya on the southern side of the Kola Peninsula.

Fluorine is present in several minerals besides flurospar on the Khibine and Lovozero tundras. The most important deposits are in the apatite ore on the Khibine tundra. The apatite ore contains about 3% fluorine, which represents enormous quantities of fluorine. The fluorine is extracted by chemically processing the apatite ore.

The lovchorrite ore on the Lovozero tundra contains 5.5% fluorine. Flurine is not extracted from this ore at present. Also on the Lovozero tundra there are appreciable quantities of the sodium fluoride mineral willaumite, which elsewhere in the world is considered a very rare mineral. As far as is known, this mineral is not being mined.

The Russians feel that there is a possibility of their finding cryolite both on the Khibine tundra and the Lovozero tundra.

Literature:

"The Minerals of Northern Europe," Berlin, 1942

A. E. Fersmann: "The Useful Minerals of the Kola Peninsula," Moscow-Leningrad, 1941 (Russian)

Note: At the end of the Yugor Road - on the Pay Khoy Peninsula (on the mainland before Novaya Zemlya) - there are the Amderma fluorspar mines, the largest fluorspar deposit in the European part of the Soviet Union. In 1939, 200,000 tons of fluorspar were produced there.